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WHY BE CONCERNED ABOUT MOISTURE IN HERMETIC PACKAGES ?

Moisture-related failure of microelectronic components have been prevalent throughout the Microelectronics Industry for many years. In the mid-1950s, Crawford and Weigand[1] showed that water vapor was the greatest contamination problem in standard relays resulting in corrosion of contact materials. This problem still persists today. In 1966, Eisenberg, Brandewie and Meyer[2] found that device reliability was influenced by the package's internal atmosphere. It was noted that low temperature applications can increase the corrosion of aluminum through the following sequence of reactions :

$$6HCl + 2Al \rightarrow 2AlCl_3 + 3H_2\uparrow \qquad (1)$$

$$AlCl_3 + 3HOH \rightarrow Al(OH)_3 + 3HCl \qquad (2)$$

$$2Al(OH)_3 + \text{aging} \rightarrow Al_2O_3 + 3H_2O \qquad (3)$$

The conclusion drawn was that if the package were hermetic and dry, corrosion of the aluminum would stop after step (1) had gone to completion. If the water were present, the reaction would continue until the exposed aluminum was completely reacted.

Over the years, moisture related failure mechanisms have been well-documented and include :

- Electrical leakage and device instability
- Metal migration such as dendritic growth and whisker formation
- Corrosion of aluminum wire and metallization
- Bond pad corrosion
- Leaching of ionic species
- Nichrome etching
- Chip capacitor delamination

Though these moisture-related failure modes have been long appreciated, even today they are commonly ignored or misunderstood. Three of the most common failure modes encountered are: metal migration, corrosion and device instability.

The only factors required for metallic migration to occur are a difference in potential between two adjacent conductors, the presence of ionic contaminants and moisture. The ions, with moisture as a carrier, enable the conductor to migrate from the more negative conductor to the more positive conductor once a bias is applied. With time, a short circuit is formed between the conductors. Only minute quantities of ionic contaminants are necessary to cause this failure mode. Gold, for example, requires less than 10^{-7} grams/cm^2 of KCl with a 12 volt applied bias in order to migrate.

The manner in which corrosion occurs may vary with the contaminant present, but the end result is generally fatal for the device. One of the first (ref. Crawford and Weigand[1]) and most commonly observed forms of corrosion is the action of chlorine and water to oxidize metallization, in which chlorine acts as a catalyst and the reaction proceeds until either all of the metallization or all of the water is consumed.

Active device functions can also be affected by moisture. Water in the presence of sodium will supply a hydrogen atom which will rapidly diffuse through the passivating layer(s) of the semiconductor and form a charge plane at the Si-SiO$_2$ interface. The manner in which it affects the semiconductor depends on the nature of the device and the quantity of the contaminant. Effects such as increased leakage currents, failure of Field Emission Transistors (FETs) to enhance or deplete properly or total lack of function are not uncommon.

Where does this entrapped moisture, which can be so potentially fatal to device reliability, come from? The belief that a low moisture reading on the sealing box hygrometer will insure a dry ambient inside the device is a wide spread myth. While it is extremely important to monitor and maintain a low moisture sealing environment, historically, this has not been the primary source of high internal moisture levels.

In fact, the two major sources of moisture are: (1) the water adsorbed/absorbed on the surface of the package walls and other materials contained within the cavity of the device and (2) a loss of package hermeticity. With this in mind, the following list summarizes some potential sources of moisture in microelectronic devices:

1. Adsorbed/Absorbed Moisture in Package Parts and Materials

The following may be sources of moisture when inappropriate times and/or temperatures are used during preseal bakeout or when exposure of parts and materials to atmosphere occurs between bakeout and sealing:

a) Package part surfaces

b) Bubbles or microcracks in glass / lead / metal interfaces

c) Base-sidewall junction

d) Internal Plating

e) Polymeric Materials :

- Thermal decomposition
- Trapped gasses under large area devices and substrates
- Excess of curing agent
- Moisture gettering materials (which allow more moisture to be stored within the package so that when the device is heated, the moisture-rich getter may release large amounts of water, increasing the potential for failure)

f) Particulate matter (which may outgas moisture or provide surface active sites and secondary valence forces allowing moisture to condense at a much higher temperature than the normal ambient dewpoint)

g) Human contamination during assembly

2. Loss of Package Hermeticity

a) Loss of hermeticity due to handling, installation or operation of a device

b) Temporary loss of hermeticity when bombing pressures are applied during leak testing

c) Rework of poor package seals

3. Sealer Dry Box Conditions

a) Leak in sealer dry box or lines

b) Poor sealing gas source

Keeping the device as dry as possible during fabrication, assembly and testing cannot be overly emphasized. To protect the part during its lifetime, a sufficient preseal bakeout followed by hermetic sealing of the part in an inert atmosphere with no interim exposure to humidity will help to ensure that the device will function as it was designed.

REFERENCES

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